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Freshwater Food Habits of Salvelinus malma (Walbaum) on Amchitka Island, Alaska

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FRESHWATER FOOD HABITS OF *Salvelinus malma* (Walbaum)

ON AMCHITKA ISLAND, ALASKA

by

John F. Palmisano

A thesis submitted in partial fulfillment
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John F. Palmisano

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On Amchitka Island, Alaska

by

John F. Palmisano, Master of Science

Utah State University, 1971

Major Professor: Dr. William T. Helm
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Stomach contents of 3,672 Dolly Varden char collected from September 1967 to November 1968 were examined to determine the food habits of this species. Of these, 3,100 (86%) had food in their stomachs. Aquatic invertebrates (Insecta and Crustacea) comprised over 90% of the diet. Food habits varied with habitat. Aquatic insects were most important in the diet of stream fish while aquatic insects and crustaceans were most important in the diet of lake fish. Food habits of lake fish were related to lake bottom type and access to the sea. Fish in landlocked lakes fed primarily on aquatic insects, fish, and fish eggs. In lakes with access to the sea, crustaceans, followed by aquatic insects, were the major food items in those with firm bottoms adjacent to shore while aquatic insects, followed by crustaceans, were the major food items in those with muck bottoms adjacent to shore. As fish size increased, feeding activity decreased and aquatic insects became less important in the diet while crustaceans and fish became more important. During summer, feeding activity was highest for lake fish while it was highest during autumn and summer for stream fish. Aquatic insects were the dominant food item in summer while crustaceans and fish were dominant in spring and autumn. Mature and immature fish of similar size ate similar organisms. Mature fish, however, fed more sporadically prior to spawning. Feeding activity was highest during daylight hours. Dolly Varden selected larger food items, such as insects and amphipods and ignored small items such as nematodes and oligochaetes.

(86 pages)

INTRODUCTION

Food study background

Many previous food studies were initiated to investigate predation by Dolly Varden, *Salvelinus malma* (Walbaum), on the eggs, fry, and smolts of the economically important Pacific salmon. Armstrong and Morton (1969) found 60 papers on food studies while compiling a Dolly Varden bibliography. These papers were from the United States, the Soviet Union, Canada, and Japan. Most studies occurred in Alaska and many were on Dolly Varden collected from saltwater. Often salmon or salmon eggs observed in Dolly Varden stomachs received much attention while insects and crustaceans, even when abundant, were listed as "insect material" or "other animal food" or grouped into a miscellaneous category. The works of Nelson (1959) and Roos (1959) from Alaska, Savvaitova and Reshetnikov (1961) from Siberia, and Nishio (1934) from Japan contain a complete description of Dolly Varden freshwater food habits.

Most food studies have been brief. DeLacy (1941) stated that seasonal collections of Dolly Varden stomachs were made at Cultus Lake in British Columbia but failed to cite the study. Other studies have lasted over a number of years but food samples were collected only during spring and summer months.

No food studies in the Aleutian Islands, the site of this study, were found in the literature. Most food studies occurred on the mainland of North America and Asia and this must be kept in mind when comparisons of data are made.

The *Salvelinus alpinus* complex

There are three distinct groups of chars in North America: *Salvelinus namaycush*, *S. fontinalis*, and the *S. alpinus* group. Each of the first two groups is considered a single species by most taxonomists (McPhail, 1961). The third group, circumpolar in distribution, has an undetermined number of species and is referred to by McPhail (1961) as the *S. alpinus* complex. Several authors consider Dolly Varden a subspecies of the arctic char, *S. alpinus*, and refer to it as *S. alpinus malma*, while others consider it a distinct species, *S. malma* (DeLacy and Morton, 1942; McPhail, 1961). McPhail (1961) and DeLacy and Morton (1942) consider Dolly Varden a separate species from the arctic char based on morphometric and meristic differences between the two forms (Table 1).

A total of 200 char was examined to determine which species of the genus *Salvelinus* was present on Amchitka. Gill raker and pyloric caeca counts indicated that only *S. malma* was sampled (Table 1).

Dolly Varden forms

There are two distinct forms of Dolly Varden in North America. One form occurs in the Aleutian Islands and south of the Alaska Peninsula while the other occurs north of the Alaska Peninsula (McPhail, 1961). The southern form has 8-12 rakers on the lower limb of the first arch while the northern form has 11-14 gill rakers. McPhail (1961) speculates that the two forms may have originated from a single population divided by glaciation.

Table 1. Means ($\bar{X}$) and ranges (R) of meristic characters of *Salvelinus malma* and *S. alpinus* and means and ranges of gill raker and pyloric caeca counts from 200 char from Amchitka Island, Alaska, 1968

Character		*S. malma*[a]	*S. alpinus*[a]	Amchitka char
Gill rakers[b]				
Upper arch	$\bar{X}$	8	10	7.7
	R	5-11	7-12	7-8
Lower arch	$\bar{X}$	10	13	10.0
	R	8-12	12-15	8-12
Total	$\bar{X}$	18	23	17.8
	R	15-22	21-26	16-19
Pyloric caeca	$\bar{X}$	30	45	29.5
	R	21-39	30-64	17-48
Scales on lateral line	$\bar{X}$	240	220	
	R	218-254	195-263	
Vertebrae				
Abdominal	$\bar{X}$	37	39	
	R	34-38	37-41	
Caudal	$\bar{X}$	25	25	
	R	24-29	23-27	
Total	$\bar{X}$	62	65	
	R	60-64	63-67	

[a]From McPhail (1961), and DeLacy and Morton (1942, Karluk Lake on Kodiak Island, Alaska

[b]Number on the first arch

Distribution and life history

Dolly Varden occur in coastal drainages of the North Pacific Ocean from northern California around the Aleutian Archipelago to Japan and Korea (DeLacy, 1941; McPhail, 1961). They are primarily anadromous except those populations in the southern extremes of their range and landlocked populations.

Dolly Varden migration studies by DeLacy (1941), Revet (1962), and Armstrong (1965a) conducted in Alaska indicated that Dolly Varden migrate to saltwater in spring and return to freshwater in autumn. Average time spent at sea ranged from 52 days in Revet's (1962) study to 116 days in Armstrong's (1965a) study. Not all fish migrate every year. Smaller fish spend fewer days in saltwater than larger fish or do not migrate at all. Dolly Varden tend to return to the stream from which they migrate although some straying does occur. Migratory Dolly Varden are suspected to over-winter in lakes. Armstrong (1965a) found no Dolly Varden in saltwater in December, January, February, and March and no stream movement was observed from mid-December to mid-March. Spawning occurs from late autumn to early winter.

Objectives

The purpose of this paper is to describe qualitatively and quantitatively the food habits of Dolly Varden char captured from September 1, 1967 to November 12, 1968 on Amchitka Island, Alaska. Particular attention will be focused on changes in food habits with habitat (stream versus lake), fish size, time (seasonal and diurnal), and sexual development. A comparison will be made of bethic fauna abundance and benthic fauna utilization by char with the use of bottom samples. The food habits of threespine stickleback (*Gasterosteus aculeatus*), Aleutian sculpin (*Cottus aleuticus*), and silver salmon smolts (*Oncorhynchus kisutch*) feeding in the same area as the char will be examined to help determine if Dolly Varden select their food or merely eat what is present.

DESCRIPTION OF STUDY AREA

Aleutian Islands

The Aleutians stretch in a southwesterly arc 1,700 kilometers (km) into the North Pacific from the mainland of Alaska toward the Kamchatka Peninsula of the Soviet Union. The 76 named islands in the group comprise over 1.2 million hectares (ha). Many of the islands are moutainous and contain active volcanoes. No island is longer than 144 km nor wider than 64 km. The larger islands contain freshwater streams and lakes. Alpine heaths, meadows, and tundra comprise the Aleutian flora. The islands are treeless except for dwarfed willow and alder. Shorelines are rocky and are usually marked with stands of beach grass. Precipitation, fog, and clouds characterize the climate. The area is noted for frequent and violent squalls. Rain is copious in the summer and snow is prevalent during the winter. Summer temperatures average 8 C while temperatures fluctuate around 0 C in winter. The warm Japanese Current moderates winter temperatures and keeps the sea's ice free (Anonymous, 1966).

The islands are rich in wildlife. Except for seven of the eastern islands the chain constitutes the Aleutian Island National Wildlife Refuge. Birds are the most obvious feature of Aleutian wildlife. North American and Asiatic migratory species and resident populations of sea birds, shore birds, and land birds are found in the chain. Only the four eastern islands have terrestrial mammals such as brown bear, caribou, lemmings, ground squirrel, vole, and shrew. Marine mammals such as the sea otter, sea lion,and seals are dominant elsewhere. The economically important salmon and Alaska king crab occur in the surrounding waters of the chain (Anonymous, 1966).

Amchitka

Amchitka Island (51°30' North latitude and 179° East longitude), the site of this study, is in the Rat Island Group of the Aleutian Chain of Alaska. It is approximately 1,000 km east of the Kamchatka Peninsula and 2,200 km southwest of Anchorage (Figure 1). The island lies in a northwesterly-southeasterly direction and is 68 km long and averages 4.8 km in width (Holmes and Narver, 1968).

The geology of Amchitka is characterized by volcanic materials such as lava flows, tufa, scoria, ash, and breccia. Basement rock is exposed over a large portion of the island. Soils consist of clay and organic material varying in thickness from one-fourth to six meters in depth over most of the island with the exception of some mineral soil on the beaches (K. R. Everett, personal communication, September 1968).

The island's northwestern section is mountainous with elevations up to 360 meters while the southeastern portion has a maximum elevation of 105 meters. The southern two-thirds of the island consists of rolling marine or oceanic tundra (no permafrost) with many shallow ponds from a few to several hain area, generally one-third to two meters deep. This area is drained by numerous small streams. The coastal area is rocky with many sea stacks and has extensive kelp beds.

Amchitka has over 130 species of flowering plants, including grasses, sedges, and the dwarfed willow (C. Amundsen, personal communication, July, 1968). The island also has a large number of mosses, algae, and lichens.

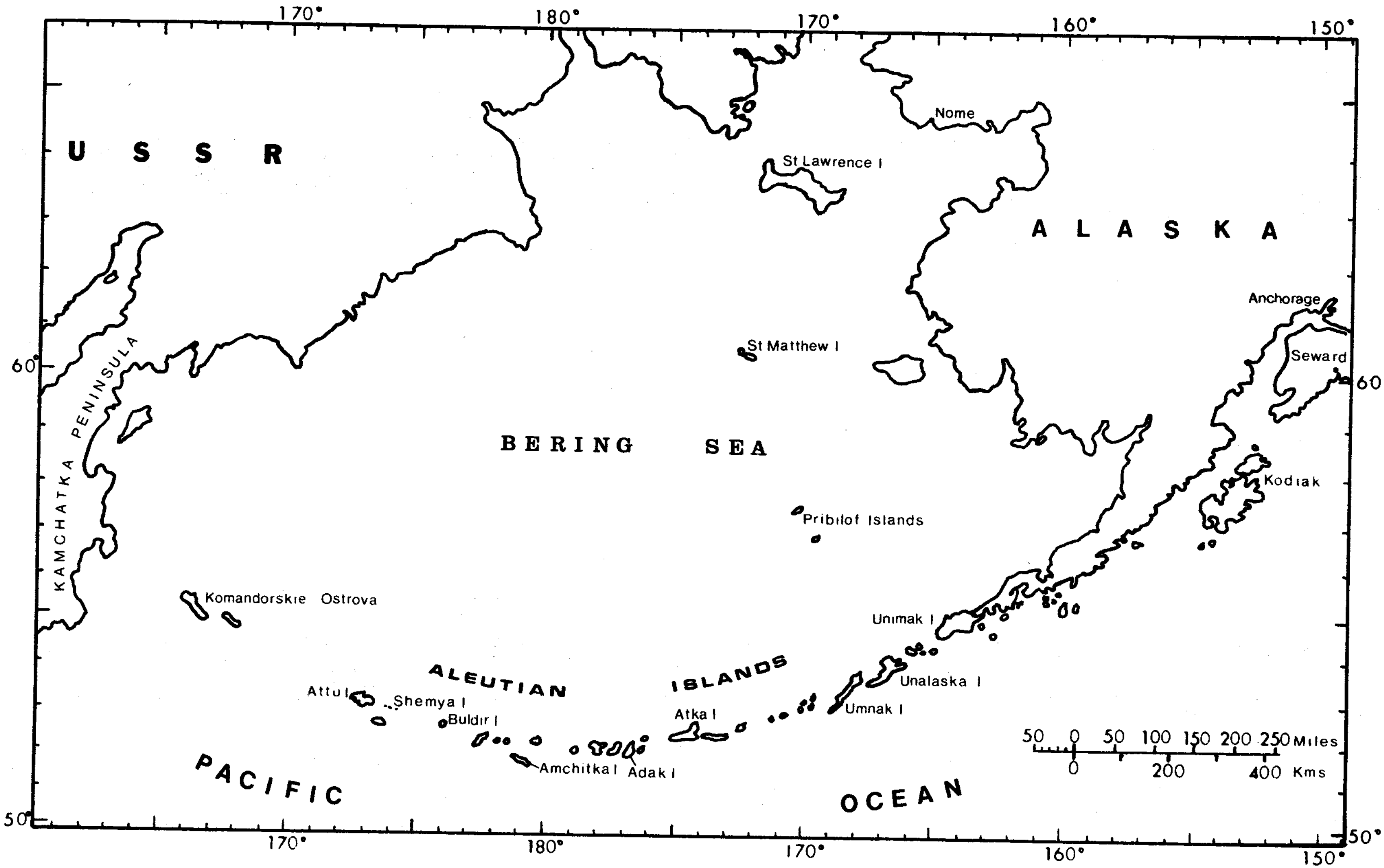

Figure 1. Map of the Aleutian Islands which shows the location of Amchitka Island.

According to Clebsch (1968) the vegetation of Amchitka can be separated into two major classifications of upland and lowland topo-environments. This division was based on topography and restriction of drainage. A third type, the "dry" beach topo-environment, is a grass community situated on a well-drained mineral substrate above high tide.

The lowland topo-environment is best described as a wet meadow vegetation with sedge and lichens dominant in the wettest area with grass, sub-shrubs and sedges becoming more apparent as drainage improves (Clebsch, 1968). This vegetation has a substrate of sedge-lichen peat one-third to one-half meter in depth on moderate slopes to over 5 meters on lower slopes. This lowland tundra is on terrain which varies from flat to moderate slopes and contains many small ponds and streams.

Grass and crowberry, *Empetrum nigrum*, are the dominant flora on the well-drained upland topo-environment (Clebsch, 1968). Sedges and *Juncus* sp. are also prevalent in the well-drained areas. These upland sites are situated along established streams, around permanent lakes and on sea cliffs and slopes with well developed soil. This community reflects lesser accumulations of peat and well-drained soil.

The most extensive community in terms of area is the crowberry-grass-sedge meadow at the wetter end of the upland topo-environment and the second most extensive community is the crowberry-sedge-grass meadow at the dry end of the lowland topo-environment (Clebsch, 1968).

The island's climate is created because of its location along the North Pacific belt of storms. Summers are cool and cloudy while winters are relatively warm. Both daily and seasonal temperature variations are relatively slight. Mean annual temperature is 4.5 C. Extremes of -9.4 C and 18.3 C have been recorded. Amchitka has an annual precipitation range of 76 to 89 centimeters (cm) which includes a mean annual snowfall of 178 cm. Visibility is less than 5 km during 83% of the summer and 60% of the year. Cloud ceilings average less than 300 meters. Summer winds average 32 to 40 km per hour while winter velocities rarely exceed 160 km per hour, though winds of this speed are not rare (Holmes and Narver, 1968).

Amchitka was once the home of hundreds of Aleuts. Many were murdered or died of disease following the arrival of Russian sea otter hunters (R. Sense, personal communication, Oct. 1967).

Amchitka was occupied by U. S. Military Forces (reportedly as many as 10,000 men at peak periods)(Kenyon, 1961). The Army abandoned the island after the war leaving behind hundreds of buildings and pieces of machinery as well as roads and runways.

Amchitka was again used by the United States Government in 1965 for project Long Shot. This was an underground nuclear detonation used as a seismic detection experiment.

Amchitka has an abundance of wildlife. It has many sea birds: petrels, cormorants, gulls, auklets, puffins, and terns; shore birds: oystercatchers, rock sandpipers, phalaropes; land birds: bald eagles, falcons, jaegers, ptarmigan, rosy finches, Lapland longspurs, sparrows, snow buntings; waterfowl: eider, harlequin ducks, emperor geese, mallards, pintails, mergansers, common teal; and loons: common, arctic, and redthroated.

There are over 35 species of insects, mostly Diptera, on the island as well as spiders and other terrestrial invertebrates. The lakes and contain Dolly Varden, threespine stickleback, Aleutian sculpin, silver salmon smolts, numerous invertebrates, algae, mosses, and rooted aquatic vascular plants.

The surrounding sea contains rich kelp beds and hundreds of species of invertebrates. There are pink, silver, king, and sockeye salmon as well as halibut, ocean perch, sculpin, greenling, and other fish in the offshore waters. Some of the salmon (mostly pink) use island streams for spawning purposes in autumn. Marine mammals consist of the sea otter, sea lion, harbor seal, and whales.

Amchitka contains over 3,000 ponds and lakes. Most are located in the southern half of the island. McCann (1962) randomly selected 60 ponds for examination during the summer of 1962. Area ranged from 0.2 to 26.8 ha while the average shoreline length was 37.4 meters. The maximum depth observed was 3.3 meters. Over half of the ponds had a water color described as clear while 20 were brown. Shallow ponds with silt bottoms often became turbid during periods of high wind. Water temperature varied from 8 C in early May to 18.5 C in July. The pH varied from 5.2 to 9.0 but tended to be slightly acidic (6.5).

Dolly Varden occurred in only 5% of the ponds while stickleback were found in 58% of them. Sculpin were found only in Jones Lake (DA) and stream DB (Figure 2).

Smaller ponds tended to be shallow with silt bottoms and were usually rich in benthic fauna. Both aquatic and bank vegetation were generally absent. Some of these ponds were found to be intermittent. Some large lakes had open sand and gravel beaches and extensive beds of rooted aquatic vegetation. Others had undercut banks due to extensive wind action. Lakes in rocky regions had borders of large angular

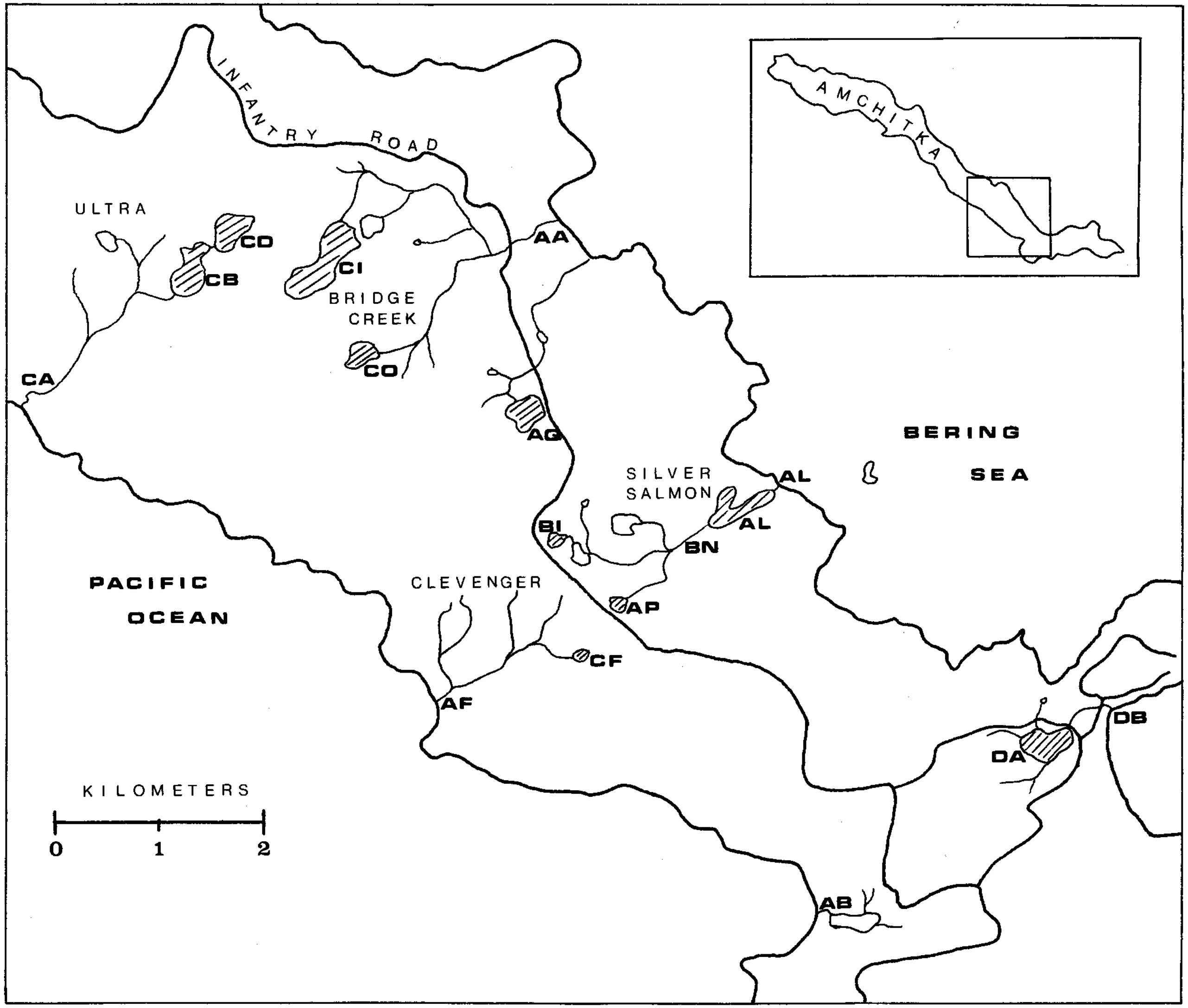

Figure 2. Map of Amchitka which shows the location of the stations sampled from December 1967 to November 1968.

rocks and silt covered centers. Lake basins were level and shorelines were extremely regular.

Koob (1968) sampled 68 lakes and ponds in the southern half of the island in 1968. Lakes sampled were generally less than one ha in area and averaged about one-half meter deep. Bottom sediments consisted of fragmented local bed rock, pebbles, sand, and relatively undecomposed detritus. Oxygen concentrations in surface waters in all lakes tested were found to be near 100% saturation.

The streams of Amchitka have uniform physical characteristics with a division appearing between the northwestern one-third and the rest of the island. The streams in the north are in mountainous terrain with elevations up to 390 meters. Here watersheds have drops of 300 meters in less than 3 km and streams have steep gradients and high velocities. Maximum flow on streams sampled did not exceed 1.5 cubic meters per second. Bottom material consisted of large diameter rubble. Stream width averaged 1.5 meters and bank vegetation was sparse. Fish cover occurred in plunge pools and undercut banks (Neuhold and Helm, 1968).

Streams in the southeastern portion of the Island have low elevations and gentle gradients and meander to a considerable extent. Stream flow seldom exceeded 0.3 cubic meter per second except during flooding. Banks are covered with lush growths of grasses and sedges during summer. A canopy is often formed over the watercourse which completely restricts direct sunlight from reaching the stream and provides excellent fish cover. Stream bottoms are covered with undecomposed detritus and silt. Moss, filamentous algae, diatoms, and rooted aquatic vascular plants are present throughout the streams. Oxygen concentrations were found to be near 100% saturation.

<u>Sampling areas</u>

Lakes and streams were sampled in September 1967 to gain information on variation in the aquatic environment and availibility of Dolly Varden (Figure 3). After a similar survey in December 1967 seven watersheds were selected as study areas: Bridge Creek, Silver Salmon, Quonset, Jones, Ultra, Rifle Range, and Clevenger. These watersheds were in the southern third of the island, the area containing the most lakes and streams per unit area (Figure 2). The sampling areas were representative of the watersheds present. They were selected for their known fish population and distribution.

Bridge Creek, Silver Salmon, Quonset, and Jones watersheds flow into the Bering Sea. Ultra, Rifle Range, and Clevenger watersheds empty into the North Pacific. The seven watersheds are within an area of 40 square km.

The major stream in each watershed constituted the stream sampling area. No stream in Quonset watershed was sampled. Streams were typical of those in the southern portion of the island (Table 2). Three lakes from Silver Salmon, two each from Ultra and Bridge Creek, and one each from Rifle Range, Jones, and Quonset served as lake sampling stations. No lake in Clevenger watershed was sampled. Physical features of lakes varied (Table 3) but were similar to those described by McCann (1962).

Lakes were placed in one of three class types based on bottom type, amount of rooted aquatic vegetation, or access to the sea via a permanent drainage system. Type II lakes had outlets that reached the sea only during times of floods (if at all) and could be considered landlocked during most of the year. Isolation rather than bottom type or amounts of rooted vegetation was the basis for classifying lakes as

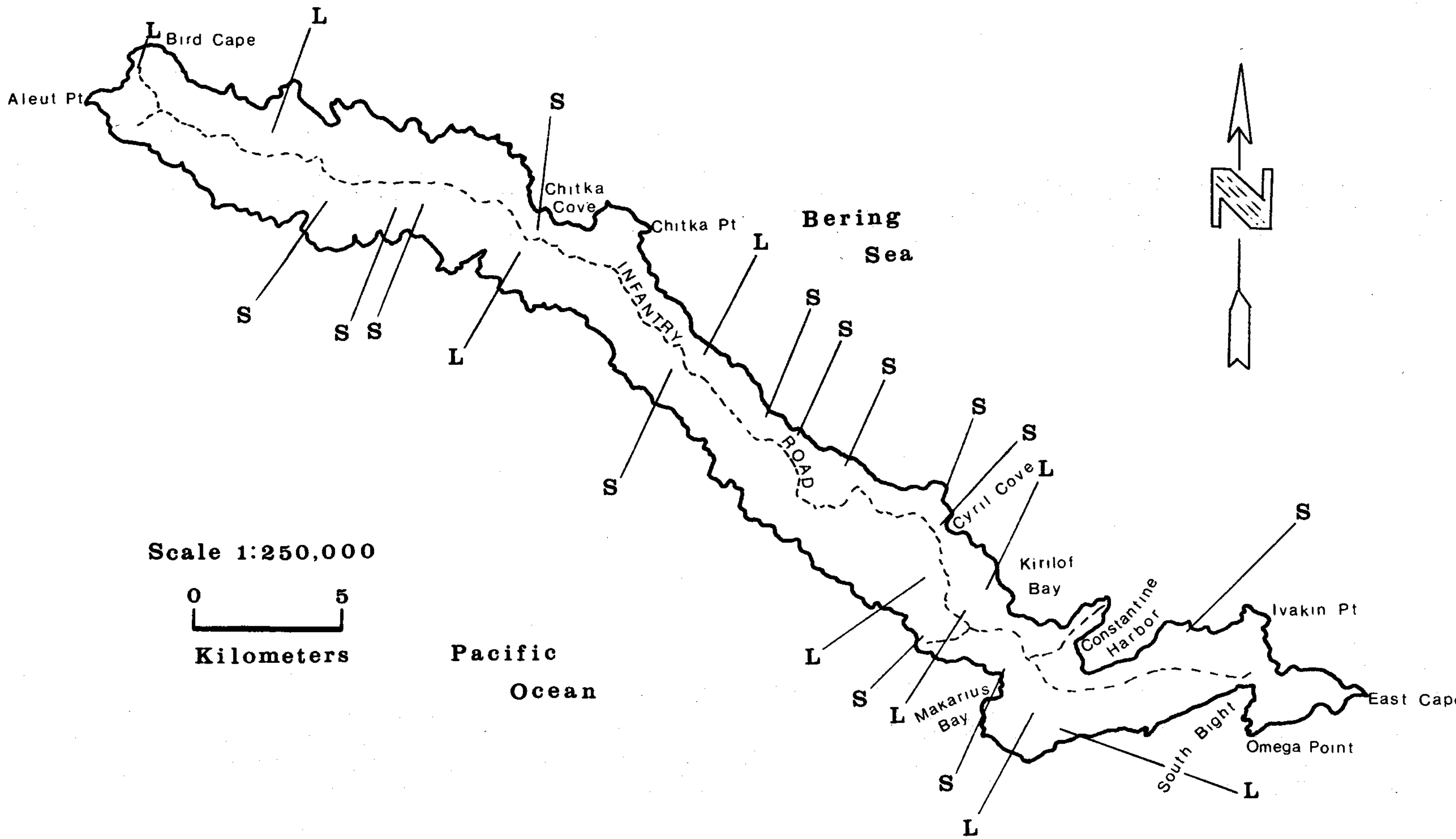

Figure 3. Map of Amchitka which shows the location of streams (S) and lakes (L) sampled in September 1967.

Table 2. Physical features of stream stations. Each station represents a different stream

Watershed	Station	Mean Annual Flow in Meters^3/sec	Width in Meters		Depth in Meters		Bottom Type
			Avg	Max	Avg	Max	
Bridge Creek	AA	0.111	0.9	1.2	0.6	0.9	Silt
Silver	BN	0.015	0.6	0.9	0.4	0.9	Silt
Salmon	AL	0.030	0.9	1.5	0.4	0.6	Gravel
Jones	DB	0.012	0.6	0.9	0.3	0.4	Gravel
Ultra	CA	0.111	0.9	1.2	0.6	0.7	Silt
Rifle Range	AF	0.105	1.2	1.5	0.6	0.9	Silt
Clevenger	AB	0.012	0.6	0.9	0.4	0.6	Gravel

Table 3. Physical features of lake stations. Each station represents a different lake

Watershed	Station[a]	Bottom Type		Aquatic Vegetation Cover (percent)	Depth in Meters		Area in Hectares
		Shore	Center		Avg	Max	
Bridge Creek	CI	Gravel	Silt	5	0.8	0.9	27.9
	CO	Detritus	Clay	5	1.2	1.3	8.9
Silver Salmon	AL	Gravel	Silt	10	0.9	1.1	12.7
	AP	Rock	Silt	75	0.9	1.2	3.8
	BI	Gravel	Silt	10	0.6	0.9	3.8
Quonset	AQ	Gravel	Silt	10	1.5	1.8	12.1
Jones	DA	Silt	Silt	25	1.8	2.3	15.4
Ultra	CB	Sand	Silt	10	1.5	1.8	12.5
	CD	Rock	Silt	10	1.5	1.8	6.9
Rifle Range	CF	Rock	Silt	75	0.9	1.2	2.5

[a]See Figure 2 for letter-code designation

type II. Type I and III lakes had seasonally uninterrupted drainage to the sea and were separated from each other on the basis of bottom type and amounts of rooted vegetation. Type I lake bottoms adjacent to the shore were composed of gravel and flat and angular rocks covered with filamentous algae. Lake bottoms away from shore were silt covered and had 10% or less cover of rooted aquatic vegetation. Type III lakes had 25% or greater cover of rooted aquatic vegetation, muck bottoms adjacent to shore with some angular rocks, and silt covered bottoms away from shore. Ten lakes used in this study are listed according to type in Table 4.

Table 4. Ten lake stations listed according to type[a]

Type I	Type II	Type III
AL	CI	AP
AQ	CO	CF
BI		DA
CB		
CD		

[a]See Figure 2 for letter-code designation

The watersheds sampled occurred in the upland topo-environment as described by Clebsch (1968). Each lake and stream sampling station was identified by two boldface letters, i.e. AA, CO (Figure 2).

METHODS AND MATERIALS

Lake collections

Dolly Varden were captured from lakes with a 6.1 meter-long by 1.2 meter-deep beach seine (2%), sport-fishing tackle (3%), and monofilament experimental gill nets (95%). Gill nets were 38.1 meters long by 1.8 meters deep with 7.6 meter sections of 1.2, 2.5, 3.8, 4.2, and 5.1 cm mesh (bar measure).

Gill nets were set by walking them into position. Preliminary settings revealed that larger numbers of fish were caught with settings perpendicular to and terminating at the shore. This method was used for the remainder of the study. When lakes were frozen, gill nets were set under the ice. Gill nets were set in late afternoon or evening and tended early in the day.

Sport fishing and seining were most productive when conducted near shore. They were used primarily during daylight hours but also at night.

Stream collections

Electro-fishing with a 220-volt, 400 cycle, AC backpack generator accounted for all stream fish collected. Collecting always proceded in an upstream direction. "Shocked" fish were washed into a dip net by the current or actively captured by the collector. Streams were not sampled during periods of heavy snow and high winds. Snow drifts covered the stream courses rendering them invisible and unaccessable. Stream samples were taken day and night.

General procedures

Collections were made throughout the year in lakes and streams to determine variation in food habits due to season and habitat. Biweekly collections were made from June to September while monthly collections were made in March, May, October, November, and December. Not all stations were sampled each month (Table 5).

Captured fish were measured (total length) in millimeters and weighed in grams and individual stomachs were removed and placed in a 10% formalin solution within 24 hours of capture. When delays occurred samples were refrigerated until processing began.

Gonadal development was noted and fish were categorized as mature (would spawn in autumn) or immature. Fish were placed in one of five size classes: 23-99, 100-199, 200-299, 300-399, and 400-562 millimeters. Food habits data were also catagorized by habitat (stream, lake, and lake type).

Stomach contents from the esophagus to the pylorus were analyzed. Frequency (percent) of occurrence, number, and volume of specific food items from fish of a desired category were determined by combining such items from all stomachs in that category. Volume of individual stomachs, as well as total volume from above, was determined by water displacement. A graduated centrifuge tube was used for the measurement. Frequency of occurrence of each food item was obtained by dividing the number of fish containing a specific item by the total number of fish containing food. Degree of stomach fullness was computed by comparing the volume of a particular stomach to the volume of the fullest stomach of a fish of comparable size (usually within 20 to 40 millimeters) caught in the same month at the same station. Figure 4

Table 5. Summary of the number of Dolly Varden collected on Amchitka from December 1967 to November 1968

Stations	March	May	June	July	August	September	October	November	December	Total
Lakes										
AP	22	---	14	18	15	17	15	2	12	115
AL	--	13	36	21	3	--	49	--	--	122
BI	2	--	--	--	3	2	--	--	8	15
CI	--	7	8	10	1	--	--	--	--	26
CO	--	10	14	17	11	--	--	--	--	52
CB	--	--	52	22	19	--	50	20	--	163
CD	--	--	49	17	11	--	11	9	--	97
CF	32	4	11	18	15	5	10	17	--	112
AQ	--	--	--	107	80	33	16	10	36	282
DA	--	--	26	162	183	106	76	30	--	583
Total	56	34	210	392	341	163	227	88	56	1567
Streams										
BN	--	13	13	13	--	--	--	--	1	40
AL	--	11	16	--	--	--	--	--	--	27
AA	27	22	14	25	18	19	24	35	--	184
CA	27	--	37	19	26	--	--	--	--	109
AF	--	5	2	--	10	9	--	--	--	26
AB	25	--	--	81	89	92	9	19	1	316
DB	--	--	52	49	61	2	3	20	--	187
Total	79	51	134	187	204	122	36	74	2	889
Grand Total	135	85	344	579	545	285	263	162	58	2456

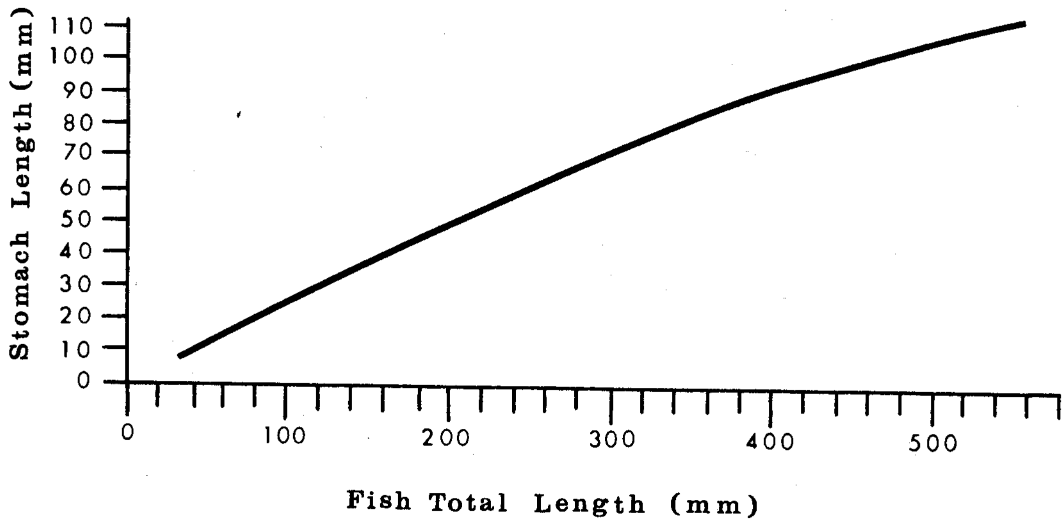

Figure 4. Fish length--stomach length relationship of Dolly Varden from 23 to 562 mm long captured on Amchitka from December 1967 to November 1968.

shows the relationship between Dolly Varden total length and stomach length. Stomach fullness was expressed by one of six categories: 100-76%, 75-51%, 50-26%, 25-5%, Trace, and 0%. The exact percent of fullness was used in the diurnal study. The "Trace" category was similar to 0% since only a single small food item or a portion thereof was present. A food item was considered "dominant" if it comprised over 50% of the stomach contents by volume.

Stomach contents were examined in vitro with the naked eye or binocular dissecting microscope. Individual food items were identified to family, genus, or species when possible with the aid of appropriate texts by Borrow and DeLong (1964), Eddy (1957), Pennak (1953), and Usinger (1963).

Stomachs collected in September 1967 were analyzed as described above except that they were not categorized by size, degree of stomach fullness or maturation.

Two streams were sampled on a 24-hour schedule to determine diurnal flucuations in food habits. Stream DB was sampled in mid-June, July, and August while stream AB was sampled on the first of July, August, and September. Six fish from DB and 10 from AB were collected eight times per day, once every three hours starting at 0800 hours. The method described in "Stream collections" was used to obtain samples. Collecting proceeded until the prescribed number of fish for each 3-hour interval was obtained. To eliminate variation in stomach fullness due to fish size, only fish from 70 to 220 mm (total length) were used. If fish of other sizes were captured they were kept but not analyzed.

A uniform portion of the stream was used for the study. This section contained riffle areas only. Width and undercuts were similar throughout. The bottom consisted of gravel with no attached or rooted aquatic vegetation. Water depth varied between 5 and 24 cm. The shoreline was open and grass-covered. No section of the stream was disturbed by the collector between collections.

Percentage composition by number of each benthic fauna group present in stomach contents was compared with its corresponding percentage composition in bottom samples to determine if a relationship existed between benthos abundance and fish utilization. Two streams, AA which drained into the Bering Sea, and CA which emptied into the North Pacific, and three lake stations, CB from lake type I, CO from lake type II, and CF from lake type III, were used. Fish samples and bottom samples from each station were collected at the same time. Each station was sampled twice a month from June to September and once during October. Fish from all size classes and from each month were pooled for each station. Pooling was necessary since monthly collections were small and fish from all size classes were not always represented. Bottom samples from each month were also pooled for each station.

Bottom samples

Bottom samples were collected from lakes with a 15.2 x 15.2 cm Ekman dredge. Stations were sampled biweekly from June to September and once in October. Two samples were taken from mud and silt covered bottoms in water 0.3 to 1.3 meters deep during each visit to a station. Samples were obtained by wading into the lake. Dredge contents were washed in a sieve-bottom bucket (with a mesh of 12 grids to the cm). The residue was placed in a plastic bag containing a 10% formalin solution. Phloxene B, a dye which stains animal tissue red (Mason and

Yevich, 1967), was added to the sample. This permitted fast and easy processing of the benthic fauna which were then recorded according to kind and number.

Benthic samples were obtained from streams with a screen sampler. This device is simply a fine-meshed screen stretched across the stream. One collector supports the screen while another moves upstream and disturbs bottom materials. Dislodged materials are deposited on the screen by the current. An area of approximately six square meters was disturbed for each sample. The sampling schedule and processing techniques for stream benthos samples were similar to those used in lake samples.

Statistical tests

Chi-square was used to test for significant differences in feeding activity due to fish size, season, and maturation. (In all tests exact numbers of fish feeding, not percentages, were used.)

Analysis of variance was used to determine the effect of time of day on stomach fullness.

Regression analysis was used to determine the correlation between benthic fauna occurrence and its utilization by fish.

Other fish species

Threespine stickleback, Aleutian sculpin, and silver salmon smolts were collected while seining and electro-fishing from May to November of 1968. Stomach analyses were made on the salmon smolts (this report) and stickleback (R. A. Valdez, 1970). To date, sculpin stomachs have not been analyzed. Procedures used in these analyses were similar to those used on Dolly Varden.

RESULTS

September 1967 collections

A total of 1,216 Dolly Varden, 1,024 from streams and 192 from lakes, was captured from 14 streams and 8 lakes on Amchitka during the first week of September 1967. In the stream sample 901 (88%) had been feeding. Insects occurred in over 90% of feeding fish and were dominant by volume in 85% (Table 6); hereafter values of food items refer only to fish with food in their stomachs. Chironomidae (midge) larvae had a frequency of occurrence of 60% while Trichoptera (caddis) larvae and Sternorrhyncha larvae were dominant by volume in 30% and 22% of the stomachs, respectively. Other were present in 15% of the fish but were dominant by volume in less than 5%.

Almost 85% (163) of the lake fish captured had been feeding. Crustaceans occurred in over 55% and were dominant by volume in 32% (Table 6). The isopod *Gnorimospheroma lutea* had the highest frequency of occurrence, 38%, followed by the amphipod *Corophium spinicorne*, 22%. *G. lutea* and *C. spinicorne* were dominant by volume in 23% and 1%, respectively. Insects occurred in 20% of the fish and were dominant in 18%. Gastropods (snails) and pelecypods (clams) were in 12% of the stomachs and were dominant by volume in 7%. Stickleback were present in 14% and dominant by volume in 4%.

General food habits

Of 2,456 fish captured from December 1967 to November 1968, 2,036 (83%) had been feeding. The diet of Dolly Varden captured on Amchitka consisted of over 50 food items (Table 7). Aquatic insects were the

Table 6. Food taken by Dolly Varden from lakes and streams on Amchitka during September 1967 expressed as percentage occurrence and dominance by volume (parentheses) in feeding fish

Food Item	Streams			Lakes		
Insects						
Chironomidae larvae	60	(5)		8	(7)	
Chironomidae pupae	52	(6)		11	(5)	
Chironomidae adults	34	(8)		3	(3)	
Trichoptera larvae	47	(30)		3	(1)	
Ephemeroptera nymphs	4	(1)		0	(0)	
Simuliidae larvae	2	(0)		0	(0)	
Simuliidae pupae	2	(0)		0	(0)	
Tipulidae larvae	1	(0)		0	(0)	
Tipulidae pupae	2	(1)		0	(0)	
Anthomyiidae adults	19	(4)		3	(1)	
Collembola	25	(1)		0	(0)	
Tehneumonidae	7	(2)		0	(0)	
Coleoptera	4	(1)		1	(1)	
Sternorrhyncha	26	(22)		0	(0)	
Other insects	8	(4)		0	(0)	
Crustaceans						
Gnorimosphaeroma lutea	3	(2)		38	(23)	
Corophium spinicorne	0	(0)		22	(1)	
Cladocera	0	(0)		14	(8)	
Copepod	1	(0)		0	(0)	
Mollusca						
Pelecypod	2	(0)		8	(4)	
Gastropod	5	(1)		8	(3)	
Fish						
Gasterosteus aculeatus	0	(0)		14	(4)	
Miscellaneous						
Nematoda	2	(0)		7	(0)	
Oligochaeta	2	(1)		0	(0)	
Acarina	5	(0)		13	(0)	
Araneida	11	(0)		3	(0)	
Other invertebrates	0	(0)		24	(18)	
Number feeding			901			163
Number empty			123			29
Total examined			1024			192

Table 7. Food items eaten by Dolly Varden on Amchitka from September 1967 to November 1968

<u>Aquatic Insects</u>

Collembola
- Smythuridae

Ephemeroptera
- Baetidae

Hemiptera
- Corixidae

Trichoptera
- Limmephilidae
- Leptoceridae

Hymenoptera
- Ichneumonidae
- Braconidae

Coleoptera
- Dytiscidae
- Hydrophilidae

Diptera
- Tipulidae
- Heleidae
- Simuliidae
- Chironomidae
  - Hydrobaeninae
- Syrphidae
- Dolochopodidae
- Empididae
- Anthomyiidae
- Psychodidae
- Phoridae
- Rhagionidae

<u>Terrestrial Insects</u>

Orthoptera

Homoptera
- Sternorrhyncha

Hemiptera

Coleoptera
- Carabidae
- Eliateridae

Lepidoptera
- Noctriidae

Diptera
- Bibionidae
- Mycetophilidae
- Sciaridae
- Ceridomyiidae
- Coelopidae
- Sphaeroceridae
- Agromyzidae

Hymenoptera
- Tenthredinidae
- Formicidae

<u>Aquatic Invertebrates</u>

NEMATODA

ANNELIDA
Oligochaeta

CRUSTACEA
Cladocera
Podocopa
Eucopepoda
Isopoda
- *Gnorimosphaeroma lutea*

Amphipoda
- *Corophium spinicorne*
- *Orchestia* sp.
- *Hyalella* sp.

MOLLUSCA
Gastropoda
- Lymnaeidae

Pelecypoda
- Sphaeriidae

ARACHNIDA
Acarina
- Prostigmata
- Oribatei

Araneida

<u>Fish</u>

Onchorhynchus gorbuscha eggs
Gasterosteus aculeatus and eggs
Cottus aleuticus and eggs

most frequently occurring food item, 80% (Table 8). Midge and caddis were the most common insects. Crustaceans occurred in 40% of the fish and were second in abundance. *G. lutea* and *C. spinicorne* were the most common crustaceans. Mollusks (snails and clams) appeared in 10% of the stomachs while fish and fish eggs appeared in 5%.

Aquatic insects were dominant by volume in 51% of the fish while crustaceans were dominant by volume in 25% (Table 9).

Food habits by habitat

A total of 889 fish was captured from streams and 1,567 from lakes. The stream fish contained 714 (80%) feeders. Aquatic insects were present in 90% of the stomachs (Table 8). Other food items and their percent occurrence were crustaceans, 12%; fish and fish eggs, 4%; and mollusks, 2%.

Aquatic insects were dominant by volume in 59% of the stomachs, crustaceans in 10%, and fish and fish eggs in 3% (Table 9).

Of 1,567 lake fish captured, 1,232 (85%) had been feeding. Aquatic insects were the most frequently occurring food item, 70%, followed by crustaceans, 50% (Table 8). Mollusks appeared in 15% and fish and fish eggs in 6%.

Aquatic insects were dominant by volume in 46% of the stomachs, crustaceans in 34%, fish and fish eggs in 6%, and mollusks in 2% (Table 9).

Of the lake fish, 672 were from type I lakes, 78 from type II, and 817 from type III. Type I lake fish had 591 (88%) feeders. Crustaceans were the most frequently occurring food item, 80% (Table 8). Aquatic insects were present in 45%, mollusks in 16%, and fish and fish eggs in 6%.

Table 8. Food taken by Dolly Varden from lakes and streams on Amchitka from December 1967 to November 1968 expressed as percent occurrence in feeding fish

Stations / Food Items	All	All Stream	All Lake	Lake type I	Lake type II	Lake type III
Insects						
Chironomidae larvae	37	52	29	22	18	36
Chironomidae pupae	31	37	27	14	9	41
Chironomidae adults	24	34	18	15	22	21
Trichoptera larvae	10	7	12	19	15	6
Trichoptera adults	4	2	5	10	6	1
Ephemeroptera nymphs	1	4	1	1	0	0
Anthomyiidae adults	3	5	3	3	9	2
Collembola	1	4	0	0	0	0
Mycetophilidae adults	2	2	2	1	12	1
Coelopidae adults	3	6	2	2	9	1
Sternorrhyncha	1	3	1	0	1	1
Other insects	14	21	10	10	18	8
Crustaceans						
G. lutea	26	6	37	50	4	30
C. spinicorne	22	4	32	52	0	16
Hyalella sp.	4	2	5	8	0	3
Orchestia sp.	2	6	0	0	0	0
Mollusca						
Pelecypoda	9	1	13	13	3	13
Gastropoda	2	1	3	5	7	1
Fish						
G. aculeatus	3	1	4	5	18	3
C. aleuticus	1	0	1	1	12	0
G. ac. & *C. al.* eggs[a]	2	1	2	1	23	1
Salmon eggs[b]	1	3	1	0	0	1
Miscellaneous						
Araneida	4	10	1	0	1	1
Nematoda	1	1	2	2	1	1
Other invertebrates	4	6	2	2	1	3
Stones	6	4	7	6	0	9
Number feeding	2036	714	1323	591	68	664
Number empty	420	175	244	81	10	153
Total examined	2456	889	1567	672	78	817

[a] eggs of *G. aculeatus* and *C. aleuticus*

[b] eggs of *O. gorbuscha*

Table 9. Food taken by Dolly Varden from lakes and streams on Amchitka from December 1967 to November 1968 expressed as percent dominance by volume in feeding fish

Stations / Food Items	All	All Stream	All Lake	Lake type I	Lake type II	Lake type III
Insects						
Chironomidae larvae	15	19	12	6	11	18
Chironomidae pupae	14	13	15	2	2	29
Chironomidae adults	10	14	7	4	21	9
Trichoptera larvae	5	4	6	9	6	3
Trichoptera adults	2	1	3	6	0	0
Ephemeroptera nymphs	1	2	0	0	0	0
Anthomyiidae adults	1	2	1	1	0	1
Collembola	0	0	0	0	0	0
Mycetophilida adults	1	1	1	0	7	0
Coelopidae adults	1	3	0	0	1	0
Sternorrhyncha	0	0	0	0	0	0
Other insects	4	6	3	3	5	2
Crustaceans						
G. lutea	13	3	19	28	1	13
C. spinicorne	11	3	15	24	0	9
Hyalella sp.	0[a]	0	0[a]	0	0	1
Orchestia sp.	1	4	0	0	0	0
Mollusca						
Pelecypod	0[a]	0	1	0	0	1
Gastropod	0[a]	0	1	1	3	0
Fish						
G. aculeatus	2	1	3	3	18	2
C. aleuticus	1	0	1	1	10	0
G. ac. & C. al. eggs[b]	1	0	1	1	13	0
Salmon eggs[c]	1	2	1	0	0	1
Miscellaneous						
Araneida	0[a]	1	0	0	0	0
Nematoda	0	0	0	0	0	0
Other invertebrates	2	4	0	0	0	1
Stones	0	0	0	0	0	0

[a] value less than 0.5 percent

[b] eggs of *G. aculeatus* and *C. aleuticus*

[c] eggs of *O. gorbuscha*

In type I lakes crustaceans were dominant by volume in 52%, aquatic insects in 30%, fish and fish eggs in 5%, and mollusks in 1% (Table 9).

Of the fish from type II lakes 68 (87%) had been feeding. Aquatic insects were present in more than 60% of the stomachs (Table 8). Other food materials and their percent occurrence were fish and fish eggs, 45%; terrestrial insects, 22%; mollusks, 9%; and crustaceans, 4%.

In type II lakes aquatic insects were dominant by volume in 45% of the stomachs, fish and fish eggs in 41%, terrestrial insects in 8%, mollusks in 3%, and crustaceans in 1% (Table 9).

The fish of type III lakes had 664 (81%) feeders. Aquatic insects appeared in more than 70% of the stomachs (Table 8). Crustaceans were present in more than 40%, mollusks in 10%, and fish and fish eggs in 6%.

In type III lakes aquatic insects were dominant by volume in 61% of the fish, crustaceans in 23%, fish and fish eggs in 3%, and mollusks in 1% (Table 9).

Lake and stream fish obtained more than 90% of their diet from the aquatic environment (Table 10). Invertebrates accounted for more than 85% of the diet in both lake and stream fish. Aquatic insects were the predominant food item in the lotic environment (74% by volume). Aquatic insects also were the dominant food item in the lentic environment (49% by volume), followed by crustaceans (33% by volume). Fish and fish eggs and mollusks were more than twice as abundant in lake fish as in stream fish. The terrestrial environment accounted for less than 7% by volume of both lake and stream diets. Insects were the most abundant terrestrial item eaten by lake and stream fish.

Table 10. Percentage volume by habitat and taxonomic classification of total stomach contents of 2,037 feeding Dolly Varden collected on Amchitka from December 1967 to November 1968

Lakes			Category			Streams
96.0			AQUATIC			93.1
	86.4		Invertebrates		87.8	
		49.3	Insecta	73.9		
		33.3	Crustacea	12.9		
		3.6	Mollusca	0.7		
		0.1	Nematoda	0.1		
		0.1	Arachnida	0.1		
		0.0	Annelida	0.1		
	7.9		Fish		3.6	
	1.7		Debris		1.7	
		0.2	Animal	1.2		
		1.3	Plant	0.4		
		0.2	Stones	0.1		
4.0			TERRESTRIAL			6.9
	4.0		Invertebrates		6.9	
		3.9	Insecta	6.6		
		0.1	Arachnida	0.3		
100.0			TOTAL			100.0

Food habits by size

Between each size class there was a significant difference in the percentage of stream fish feeding ($p < 0.05$). The smallest size class had the highest proportion of feeders and this proportion became progressively lower in each larger size class (Table 11).

There was no significant difference in the percent feeding between the first three size classes of lake fish ($p < 0.05$). The 300-399 mm group, however, was significantly different from the 400-562 mm group ($p < 0.05$) and both groups were significantly different from the first three groups ($p < 0.05$). The smaller groups had a higher percentage of feeders than the larger groups (Table 12).

Small fish more frequently consumed aquatic insect larvae than pupae or adults, crustaceans, fish or fish eggs (Table 13, 14). In the first four size classes aquatic insects were dominant by volume more often than other food items. As fish size increased, however, crustaceans, fish and fish eggs became proportionately more abundant. In the 400-562 mm lake fish aquatic insects and crustaceans were equal in abundance while the 400-562 mm stream fish fed exclusively on fish and fish eggs.

Food habits by season

During spring (March to May), summer (June to August), and autumn (September to December) a total of 130, 525, and 234 stream fish were captured, respectively. Autumn had the highest percentage of feeding fish, 86%, followed by summer, 82%, and spring, 63%. There was no significant difference in feeding between summer and autumn ($p < 0.05$) while there was a significant difference between spring and the other seasons ($p < 0.05$). May had the lowest percentage of feeding fish, 59%, while September had the highest, 94%, (Table 15).

Table 11. Percentage of each size class in each stomach fullness category and number of Dolly Varden in each size class collected in streams on Amchitka from December 1967 to November 1968

Size Class	Percentage of Stomach Fullness						Number of Fish in Each Size Class
	0	Trace	5-25	26-50	51-75	76-100	
	%						
23- 99	6	35	26	14	10	9	323
100-199	15	33	23	12	8	9	438
200-299	46	21	13	10	4	6	52
300-399	76	21	3	0	0	0	38
400-562	92	3	0	0	5	0	39
TOTAL	20	31	22	11	8	8	889

Table 12. Percentage of each size class in each stomach fullness category and number of Dolly Varden in each size class collected in lakes on Amchitka from December 1967 to November 1968

Size Class	Percentage of Stomach Fullness						Number of Fish in Each Size Class
	0	Trace	5-25	26-50	51-75	76-100	
(mm)							
23- 99	4	16	16	32	4	28	25
100-199	4	18	24	22	19	14	556
200-299	10	24	25	20	12	9	464
300-399	24	34	19	12	5	6	351
400-562	52	32	7	6	1	2	171
TOTAL	16	25	21	18	11	9	1567

Table 13. Food taken by Dolly Varden of different size classes from streams on Amchitka from December 1967 to November 1968 expressed as percentage occurrence and dominance by volume (parentheses) in feeding fish

Food Item	Size Classes				
	23-99	100-199	200-299	300-399	400-562
	mm				
Insects					
Chironomidae larvae	62 (26)	46 (14)	39 (18)	22 (11)	0 (0)
Chironomidae pupae	26 (15)	46 (12)	54 (21)	22 (11)	0 (0)
Chironomidae adults	25 (13)	42 (17)	43 (4)	11 (0)	0 (0)
Trichoptera larvae	9 (7)	5 (3)	7 (0)	0 (0)	0 (0)
Trichoptera adults	1 (0)	4 (2)	0 (0)	11 (11)	0 (0)
Ephemeroptera nymphs	5 (3)	3 (1)	0 (0)	11 (11)	0 (0)
Anthomyiidae adults	5 (2)	5 (2)	0 (0)	0 (0)	0 (0)
Collembola	4 (0)	3 (0)	4 (0)	0 (0)	0 (0)
Mycetophilidae adults	3 (1)	1 (1)	7 (4)	0 (0)	0 (0)
Coelopidae adults	4 (2)	7 (3)	7 (7)	11 (0)	0 (0)
Sternorrhyncha	4 (0)	3 (0)	0 (0)	0 (0)	0 (0)
Other Insects	16 (6)	27 (7)	11 (4)	22 (11)	0 (0)
Crustaceans					
G. lutea	2 (2)	8 (4)	11 (0)	0 (0)	0 (0)
C. spinicorne	2 (1)	5 (4)	7 (7)	11 (11)	0 (0)
Orchestia sp.	6 (4)	6 (4)	4 (4)	11 (11)	0 (0)
Fish[a]	0 (0)	1 (1)	7 (7)	0 (0)	33 (33)
Salmon eggs[b]	2 (2)	2 (2)	4 (4)	11 (11)	67 (67)
Miscellaneous					
Araneida	5 (0)	13 (2)	11 (11)	0 (0)	0 (0)
Other Invertebrates	11 (6)	10 (3)	18 (7)	0 (0)	0 (0)

[a]*G. aculeatus* and *C. aleuticus*

[b]Eggs of *O. gorbuscha*

Table 14. Food taken by Dolly Varden of different size classes from lakes on Amchitka from December 1967 to November 1968 expressed as percentage occurrence and dominance by volume (parentheses) in feeding fish

Food Item	Size Classes				
	23-99	100-199	200-299	300-399	400-562
	m				
Insects					
Chironomidae	42	26	34	32	13
larvae	(21)	(12)	(14)	(11)	(9)
Chironomidae	25	20	34	33	26
pupae	(17)	(11)	(15)	(22)	(17)
Chironomidae	21	20	22	14	9
adult	(8)	(9)	(7)	(4)	(6)
Trichoptera	13	18	10	6	7
larvae	(0)	(8)	(6)	(3)	(5)
Trichoptera	0	6	7	3	1
adults	(0)	(4)	(4)	(1)	(1)
Anthomyiidae	0	3	3	1	1
adults	(0)	(1)	(1)	(0)	(0)
Mycetophilidae	13	1	2	2	0
adults	(0)	(0)	(1)	(1)	(0)
Coelopidae	0	2	2	1	1
adults	(0)	(1)	(0)	(0)	(0)
Other	8	11	11	6	5
Insects	(8)	(3)	(2)	(3)	(0)
Crustaceans					
G.	21	43	30	37	43
lutea	(13)	(25)	(12)	(19)	(23)
C.	17	33	34	27	27
spinicorne	(8)	(16)	(15)	(14)	(15)
Hyalella	0	6	6	4	1
sp.	(0)	(1)	(0)	(0)	(0)
Mollusca					
Pelecypod	4	8	16	18	13
	(0)	(0)	(0)	(2)	(2)
Gastropod	8	4	2	3	4
	(0)	(1)	(0)	(1)	(1)
Fish					
G.	0	2	4	7	11
aculeatus	(0)	(2)	(3)	(4)	(7)
C.	0	0	2	1	2
aleuticus	(0)	(0)	(2)	(1)	(1)
Eggs of *G. ac.*	0	1	4	3	0
C. al.[a]	(0)	(0)	(3)	(1)	(0)
Miscellaneous					
Nematoda	0	3	1	0	2
	(0)	(0)	(0)	(0)	(0)
Other	8	1	2	4	0
Invertebrates	(4)	(0)	(0)	(0)	(0)

[a]Eggs of *G. aculeauts* and *C. aleuticus*

Table 15. Percentage of each month's collection in each stomach fullness category and number of Dolly Varden captured each month from streams on Amchitka from December 1967 to November 1968

Month	Percentage of Stomach Fullness						Number of Fish Caught Each Month
	0	Trace	5-25	26-50	51-75	76-100	
	%						
March	35	43	11	4	3	4	79
May	41	10	6	12	8	24	51
June	22	25	22	19	10	3	134
July	14	26	24	13	11	11	187
August	20	35	26	9	6	4	204
September	6	47	25	13	7	2	122
October	17	36	11	8	6	22	36
November	23	23	24	5	9	15	74
December	0	50	0	0	0	50	2
TOTAL	20	31	22	11	8	8	889

During spring, summer, and autumn a total of 90, 943, and 534 lake fish were captured, respectively. Summer had the highest percentage of feeding fish, 90%, followed by autumn, 76%, and spring, 71%. There was no significant difference in feeding between autumn and spring ($p < 0.05$) while there was a significant difference between summer and the other two seasons ($p < 0.05$). July had the highest percentage of feeding fish, 93%, while March had the lowest, 62% (Table 16).

During summer, numbers of midge pupae and adults per stomach were high while they were low or absent during other seasons (Table 17). These larvae were more frequent in summer and autumn than in the spring.

During summer, aquatic insect adults and pupae were abundant while their larvae, other invertebrates, fish and fish eggs were abundant during other seasons. Seasonal trends for dominance by volume of food items were similar to frequency of occurrence (Table 18).

In lake types I and III, numbers of midge larvae per stomach varied but were generally highest in summer (Table 19). In summer, numbers of midge pupae and adults were high while they were low or absent during other seasons. In spring and autumn crustacean numbers were high while they were low during the summer.

Lake type II was sampled only from May to August. In July, midge numbers per stomach were highest (Table 19). Frequency of sculpin and eggs of sticklebacks and sculpin was highest in June and July, while frequency of sticklebacks was highest in May and August.

During summer, aquatic insect adults and pupae were abundant while their larvae, other invertebrates, fish and fish eggs predominated during other seasons. Seasonal trends for dominace by volume of food items were similar to frequency of occurrence (Table 20).

Table 16. Percentage of each month's collection in each stomach fullness category and number of Dolly Varden captured each month from lakes on Amchitka from December 1967 to November 1968

Month	Percentage of Stomach Fullness						Number of Fish Caught Each Month
	0	trace	5-25	26-50	51-75	76-100	
	%						
March	38	19	7	10	6	20	56
May	15	23	15	18	3	26	34
June	16	19	26	19	11	9	210
July	7	23	28	19	13	10	392
August	9	29	23	18	12	9	341
September	22	26	14	15	13	10	163
October	22	26	18	17	13	4	227
November	32	25	14	17	9	3	88
December	23	20	9	27	0	21	56
TOTAL	16	25	21	18	11	9	1567

Table 17. Major food items taken by Dolly Varden from streams on Amchitka from December 1967 to November 1968 expressed as average number per stomach in feeding fish

Food Item	Mar	May	June	July	Aug	Sep	Oct	Nov	Dec
Insects									
Chironomidae larvae	6.4	3.0	13.8	15.7	18.7	11.7	7.3	10.8	18.0
Chironomidae pupae	0	0.5	5.2	8.3	11.8	15.9	1.3	0.3	0
Chironomidae adults	0.1	0.5	5.4	11.5	14.2	7.1	3.0	0.3	0
Trichoptera larvae	1.4	1.2	0.2	0.1	0.1	0.1	1.1	1.9	4.0

Table 18. Food taken by Dolly Varden from streams on Amchitka from December 1967 to November 1968 expressed as percentage occurrence and dominance by volume (parentheses) in feeding fish

Food Item	Mar	May	Jun	July	Aug	Sep	Oct	Nov	Dec
Insects									
Chironomidae larvae	65 (40)	30 (3)	55 (38)	53 (21)	54 (12)	47 (8)	37 (3)	54 (21)	100 (50)
Chironomidae pupae	0 (0)	10 (3)	35 (5)	42 (9)	48 (9)	63 (52)	13 (3)	7 (0)	0 (0)
Chironomidae adults	2 (2)	7 (3)	36 (12)	46 (28)	48 (20)	36 (8)	20 (7)	7 (2)	0 (0)
Trichoptera larvae	29 (29)	17 (10)	5 (3)	2 (1)	2 (1)	1 (1)	13 (3)	18 (9)	100 (50)
Trichoptera adults	0 (0)	3 (3)	4 (4)	3 (3)	2 (2)	2 (2)	0 (0)	2 (2)	0 (0)
Ephemeroptera nymphs	8 (6)	13 (7)	10 (5)	4 (1)	2 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Anthomyiidae adults	2 (2)	3 (0)	0 (0)	2 (0)	7 (3)	12 (6)	0 (0)	4 (0)	0 (0)
Collembola	2 (0)	0 (0)	3 (0)	2 (0)	10 (0)	1 (0)	0 (0)	2 (0)	0 (0)
Mycetophilidae adults	0 (0)	0 (0)	8 (5)	3 (0)	1 (1)	0 (0)	7 (3)	0 (0)	0 (0)
Coelopidae adults	0 (0)	0 (0)	1 (0)	4 (1)	8 (3)	4 (1)	37 (33)	9 (5)	0 (0)
Sternorrhyncha	0 (0)	0 (0)	0 (0)	2 (0)	7 (1)	4 (0)	3 (0)	5 (0)	0 (0)
Other Insects	6 (6)	10 (3)	27 (9)	18 (6)	30 (8)	21 (4)	23 (10)	18 (5)	0 (0)
Crustaceans									
G. lutea	0 (0)	27 (13)	10 (5)	4 (1)	9 (5)	0 (0)	3 (3)	0 (0)	0 (0)
C. spinicorne	0 (0)	40 (30)	11 (9)	1 (1)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Orchestia sp.	6 (0)	7 (7)	0 (0)	3 (3)	4 (3)	3 (0)	23 (3)	28 (19)	0 (0)
Fish[a]	0 (0)	0 (0)	1 (0)	3 (3)	1 (1)	0 (0)	0 (0)	0 (0)	0 (0)
Salmon eggs[b]	6 (6)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	28 (25)	0 (0)
Miscellaneous									
Araneida	6 (0)	10 (3)	16 (5)	12 (0)	15 (1)	0 (0)	3 (0)	0 (0)	0 (0)
Other Invertebrates	0 (0)	57 (7)	7 (1)	24 (17)	1 (0)	3 (2)	10 (3)	5 (0)	0 (0)

[a] *G. aculeatus* and *C. aleuticus*

[b] Eggs of *O. gorbuscha*

Table 19. Major food items taken by Dolly Varden from three different lake types on Amchitka from December 1967 to November 1968 expressed as average number per stomach in feeding fish

Food Item	Mar	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Lake Type I									
Insects									
Chironomid l.[a]	0	0	1.2	7.0	0.8	0.7	0.2	5.2	1.0
Chironomid p.[a]	0	0	0.3	6.6	1.6	0.1	0	0	0
Chironomid a.[a]	0	0	0.2	7.8	4.6	0.1	0.2	0	0
Trichoptera l.	0	2.0	3.4	1.0	0.2	0	0.1	2.8	0.1
Trichoptera a.	0	0	0	0.3	9.7	1.1	0	0	0
Crustaceans									
G. lutea	5.0	4.0	3.3	16.5	28.3	37.7	55.5	27.7	26.3
C. spinicorne	0	65.7	60.4	18.3	8.0	10.4	30.0	43.4	18.2
Mollusca									
Pelecypod	0	0.2	0.2	2.0	0.5	1.0	0.1	1.1	2.5
Gastropod	0	0.2	0.7	0.5	0.1	0	0.1	0.2	0.3
Lake Type II									
Insects									
Chironomid l.		31.4	45.9	62.5	0.5				
Chironomid p.		0	1.4	20.1	0.5				
Chironomid a.		0	114.	903.	54.6				
Trichoptera l.		1.1	0.5	0	0.6				
Mollusca									
Pelecypod		0.3	0	0	0.2				
Gastropod		0.3	1.0	3.0	0				
Fish									
G. aculeatus		1.4	0.4	0.1	1.8				
C. aleuticus		0	0.4	0.6	0				
G. & *C.* eggs[b]		0	181.	102.	21.7				
Lake Type III									
Insects									
Chironomid l.	1.0	2.5	5.1	29.8	2.0	1.9	12.1	14.0	0
Chironomid p.	0	0	3.0	32.1	16.7	1.0	0	0	0
Chironomid a.	0	0	0.6	25.4	10.0	0.2	0.1	0	0
Trichoptera l.	2.0	3.9	1.0	0.2	0.2	01.	0.2	0.1	7.0
Trichoptera a.	0	0	0	0.1	0.1	0.1	0	0	0
Crustaceans									
G. lutea	7.1	4.5	0.7	2.6	11.1	38.3	25.5	12.9	3.5
C. spinicorne	49.9	71.2	25.6	6.0	1.1	0.6	32.0	21.9	3.0
Mollusca									
Pelecypod	1.1	0	0.2	0.1	0.2	1.1	2.1	1.4	0
Gastropod	0.1	0	0	0.1	0.1	0.1	0	0	0.7

[a] l. = larvae
p. = pupae
a. = adult

[b] Eggs of *G. aculeatus* and *C. aleuticus*

Table 20. Food taken by Dolly Varden from lakes on Amchitka from December 1967 to November 1968 expressed as percentage occurrence and dominance by volume (parentheses) in feeding fish

Food Item	Mar	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Insects									
Chironomidae	9	17	23	37	17	31	37	52	20
larvae	(0)	(10)	(9)	(8)	(6)	(21)	(26)	(30)	(0)
Chironomidae	0	0	16	51	41	13	0	0	0
pupae	(0)	(0)	(11)	(22)	(30)	(5)	(0)	(0)	(0)
Chironomidae	0	0	8	37	27	5	3	0	0
adults	(0)	(0)	(3)	(15)	(11)	(0)	(1)	(0)	(0)
Trichoptera	23	48	34	8	4	2	8	15	30
larvae	(14)	(21)	(21)	(5)	(2)	(0)	(1)	(2)	(12)
Trichoptera	0	0	0	3	16	7	0	0	0
adults	(0)	(0)	(0)	(0)	(11)	(3)	(0)	(0)	(0)
Anthomyiidae	0	14	1	3	4	1	2	2	2
adults	(0)	(0)	(1)	(0)	(2)	(0)	(1)	(0)	(0)
Mycetophilidae	0	3	6	3	0	0	0	0	0
adults	(0)	(0)	(3)	(1)	(0)	(0)	(0)	(0)	(0)
Coelopidae	0	21	0	0	1	7	1	0	0
adults	(0)	(3)	(0)	(0)	(0)	(2)	(1)	(0)	(0)
Other	3	14	4	19	5	18	2	3	9
Insects	(3)	(0)	(1)	(5)	(1)	(7)	(1)	(0)	(0)
Crustaceans									
G.	40	48	23	17	37	65	67	33	63
lutea	(11)	(7)	(7)	(6)	(16)	(49)	(45)	(12)	(40)
C.	77	41	42	38	18	11	24	42	67
spinicorne	(66)	(34)	(32)	(18)	(4)	(0)	(10)	(17)	(28)
Hyalella	9	7	1	7	4	1	8	7	9
sp.	(0)	(0)	(0)	(0)	(0)	(0)	(2)	(0)	(0)
Mollusca									
Pelecypod	11	7	3	10	6	20	27	27	30
	(0)	(0)	(0)	(0)	(0)	(1)	(2)	(5)	(0)
Gastropod	3	7	7	3	1	2	3	2	14
	(0)	(3)	(1)	(1)	(0)	(0)	(0)	(0)	(0)
Fish									
G.	6	21	3	1	6	4	1	20	9
aculeatus	(6)	(21)	(3)	(1)	(3)	(3)	(1)	(10)	(9)
C.	0	0	1	2	1	0	1	0	0
aleuticus	(0)	(0)	(1)	(1)	(1)	(0)	(1)	(0)	(0)
Eggs of *G. ac.*	0	3	5	5	1	0	0	0	0
C. al.[a]	(0)	(0)	(2)	(2)	(0)	(0)	(0)	(0)	(0)
Miscellaneous									
Nematoda	0	7	3	2	1	2	1	0	0
	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)
Other	0	3	3	4	1	2	1	2	16
Invertebrates	(0)	(0)	(1)	(1)	(0)	(0)	(0)	(0)	(0)

[a]Eggs of *G. aculeatus* and *C. aleuticus*

During summer there was a marked reduction in the percentage of larger fish captured in lakes and streams (Tables 21, 22).

Food habits and maturation

A total of 2,030 immature and 426 mature fish was captured. Of the immature fish 1,742 (86%) had food in their stomachs whereas 295 (69%) of the mature fish had been feeding. There was a significant difference in the percent feeding between immature and mature fish ($p < 0.01$). Of the mature fish 403 were from lakes (Table 23) and 23 were from streams (Table 24). All mature fish were captured after June and the majority of these (74%) were 300 mm or longer in total length.

Of the mature lake fish 288 (71%) had been feeding. Salmon eggs had a frequency of occurrence and were dominant by volume in 44% of the fish (Table 25). Aquatic insects were present in 30% and dominant by volume in 28%. The marine amphipod *Orchestia* sp. occurred and was dominant by volume in 14% of the fish.

Diurnal food habits

Statistical analyses were performed on 384 fish captured from two streams (AB and DB) from June to September to determine the effect of time of day on stomach fullness. Fish from both streams were pooled since there was little difference in stomach fullness due to location. A two-way analysis of variance showed no significant difference in stomach fullness due to time ($p < 0.01$) but showed a significant difference in stomach fullness due to the interaction of time and month ($p < 0.01$) and a significant difference in stomach fullness due to month ($p < 0.01$). When each month was tested separately with a one-way

Table 21. Percentage of each month's collection in each size class and number of Dolly Varden captured each month from streams on Amchitka from December 1967 to November 1968

Month	Size Classes 23-99	100-199	200-299	300-399	400-562	Number of Fish Caught Each Month
	m					
March	72	23	1	3	1	79
May	17	51	10	8	14	51
June	24	51	10	7	8	134
July	38	53	5	1	3	187
August	30	60	4	2	4	204
September	40	51	6	2	1	122
October	42	30	14	11	3	36
November	35	40	6	13	6	74
December	100	0	0	0	0	2
TOTAL	37	49	6	4	4	889

Table 22. Percentage of each month's collection in each size class and number of Dolly Varden captured each month from lakes on Amchitka from December 1967 to November 1968

Month	Size Classes					Number of Fish Caught Each Month
	23-99	100-199	200-299	300-399	400-562	
	m					
March	0	39	23	25	13	56
May	0	21	32	26	21	34
June	7	31	32	20	10	210
July	1	36	39	19	5	392
August	1	41	35	17	6	341
September	1	27	16	35	21	163
October	1	41	16	24	18	227
November	1	34	25	28	11	88
December	0	21	36	23	20	56
TOTAL	2	35	30	22	11	1567

Table 23. Summary of 403 mature Dolly Varden captured from lakes on Amchitka from December 1967 to November 1968

Month	Mar	May	June	July	Aug	Sept	Oct	Nov	Dec
Number	0	0	0	101	103	77	77	22	23
Percent	0	0	0	25	26	19	19	5	6

Size Class (in mm)	23-99	100-199	200-299	300-399	400-562
Number	1	31	68	182	121
Percent	1	8	17	44	30

Stomach fullness (%)	0	trace	5-25	26-50	51-75	76-100
Number	115	134	62	50	23	19
Percent	29	33	15	12	6	5

Table 24. Summary of 23 mature Dolly Varden captured from streams on Amchitka from December 1967 to November 1968

Month	Mar	May	June	July	Aug	Sept	Oct	Nov	Dec
Number	0	0	0	1	12	1	1	8	0
Percent	0	0	0	4	52	4	4	36	0

Size Class (in mm)	23-99	100-199	200-299	300-399	400-562
Number	0	4	0	7	12
Percent	0	17	0	30	53

Stomach fullness (%)	0	trace	5-25	26-50	51-75	76-100
Number	16	5	0	0	2	0
Percent	70	21	0	0	9	0

Table 25. Food taken by immature and mature Dolly Varden from lakes and streams on Amchitka from December 1967 to November 1968 expressed as percentage occurrence and dominance by volume (parentheses) in feeding fish

Food Item	Lakes		Streams	
	Immature	Mature	Immature	Mature
Insects				
Chironomidae larvae	31 (13)	24 (8)	52 (19)	14 (0)
Chironomidae pupae	24 (13)	39 (22)	38 (13)	14 (14)
Chironomidae adults	18 (7)	20 (8)	34 (14)	14 (14)
Trichoptera larvae	14 (7)	4 (2)	7 (4)	0 (0)
Trichoptera adults	4 (3)	8 (3)	2 (1)	0 (0)
Ephemeroptera nymphs	1 (0)	0 (0)	4 (2)	0 (0)
Anthomyiidae adults	3 (1)	2 (0)	5 (2)	0 (0)
Collembola	0 (0)	0 (0)	4 (0)	0 (0)
Mycetophilidae adults	2 (1)	0 (0)	2 (1)	0 (0)
Coelopidae adults	2 (0)	1 (0)	6 (3)	14 (14)
Sternorrhyncha	1 (0)	0 (0)	3 (0)	0 (0)
Other insects	10 (3)	8 (2)	22 (7)	0 (0)
Crustaceans				
G. lutea	37 (19)	40 (21)	6 (3)	0 (0)
C. spinicorne	34 (18)	24 (8)	4 (3)	0 (0)
Hyalella sp.	6 (0)	2 (0)	2 (0)	0 (0)
Orchestia sp.	0 (0)	0 (0)	6 (4)	14 (14)
Mollusca				
Pelecypod	13 (1)	12 (0)	1 (0)	0 (0)
Gastropod	4 (1)	1 (0)	1 (0)	0 (0)
Fish				
G. aculeatus	4 (3)	6 (3)	1 (1)	0 (0)
C. aleuticus	1 (1)	1 (0)	0 (0)	0 (0)
G. and *C.* eggs[a]	3 (1)	1 (1)	1 (0)	0 (0)
Salmon eggs[b]	0 (0)	2 (2)	2 (2)	44 (44)
Miscellaneous				
Araneida	1 (0)	0 (0)	10 (1)	0 (0)
Nematoda	2 (0)	1 (0)	1 (0)	0 (0)
Other invertebrates	2 (0)	3 (0)	7 (4)	0 (0)
Stones	7 (0)	6 (0)	4 (0)	0 (0)
Number Feeding	1035	288	707	7
Number Empty	129	115	159	16
Total Examined	1164	403	866	23
Percent Feeding	89	71	82	30
Percent Empty	11	29	18	70

[a]Eggs of *G. aculeatus* and *C. aleuticus*
[b]Eggs of *O. gorbuscha*

analysis of variance the effect of time on stomach fullness proved to be significant ($p < 0.05$) during each month except September.

When a significant difference existed between time or month and stomach fullness, individual observations were ranked by the least significant difference (LSD) multiple means comparison (Table 26). In June, July, and August mean stomach fullness appeared to have been lowest during the 0500 hour observation and highest during the 0800 hour observation. Mean stomach fullness reached a peak in July and was lower in June, and lowest in August and September.

There was little difference in type of food eaten due to time of day. Aquatic insects were the major food item ingested at all hours.

Benthic fauna utilization

Eight bottom-fauna groups were present in stomachs and bottom samples collected from two stream stations (AA and CA) from June to October (Table 27). The correlation coefficient ($\underline{r}$) between percent composition in stomachs and bottom samples for all eight groups was +0.98 and was highly significant at all confidence levels for both stream stations.

Ten bottom-fauna groups were present in stomachs and bottom samples collected from three lake stations (one of each lake type) during the same time as above (Table 28). Lake CB had an $\underline{r}$ value of +0.163 ($p < 0.40$) for all 10 groups. In lake CO, $\underline{r}$ was +0.598 ($p < 0.01$) for all 10 groups. Lake CF had an $\underline{r}$ value of +0.079 ($p < 0.40$) for all 10 groups.

Table 26. Mean stomach fullness expressed in percentage by hour and month for 384 Dolly Varden captured from streams AB and DB on Amchitka from June to September 1968. (Rankings in parentheses when means in that group were significantly different; see text for explanation.)

Time (hour)	June		July		Aug		Sep		Average
0800	16	(1)	53	(1)	29	(1)	3		29
1100	15	(1)	28	(4)	26	(2)	14		23
1400	24	(1)	34	(3)	23	(3)	7		23
1700	35	(1)	21	(4)	11	(4)	18		19
2000	27	(1)	28	(4)	13	(4)	23		23
2300	29[a]	(1)	41[a]	(2)	6[a]	(5)	7[a]		21[a]
0200	16[a]	(1)	20[a]	(4)	4[a]	(5)	18[a]		14[a]
0500	10	(2)	24	(4)	4	(5)	13[a]		13
Monthly Average	22	(2)	31	(1)	14	(3)	12	(3)	

[a]dark

Table 27. Percentage composition by numbers of benthic fauna groups in Dolly Varden stomachs and bottom samples collected from two streams on Amchitka from June to October 1968

Food Item	Stream CA		Stream AA	
	Stomach	Bottom	Stomach	Bottom
Insects				
Chironomidae	90.6	93.7	98.8	86.8
Trichoptera	2.7	0	0.9	0.3
Ephemeroptera	2.2	1.9	0.3	0.7
Crustaceans				
Copepod	0	0	0	1.2
Ostracod	0	0	0	0.4
Miscellaneous				
Oligochaeta	4.5	3.4	0	8.1
Nematoda	0	0.9	0	0.6
Flatworm	0	0	0	2.9

Table 28. Percentage composition by number of benthic fauna groups in Dolly Varden stomachs and bottom samples collected from three different lake types on Amchitka from June to October 1968

Food Item	Type I Stomach	Lake CB Bottom	Type II Stomach	Lake CO Bottom	Type III Stomach	Lake CF Bottom
Insects						
Chironomidae	1.4	6.9	99.5	38.8	55.8	42.8
Trichoptera	7.8	0	0.1	0	5.1	0.2
Crustaceans						
C. spinicorne	45.2	56.4	0	0	26.3	1.0
G. lutea	44.5	0.3	0	0	9.3	0.7
Hyalella sp.	0.2	0.1	0	0	0.1	0.2
Ostracod	0	0.9	0	33.9	0.2	2.0
Mollusca						
Pelecypod	0.1	0.1	0	7.1	0.3	1.4
Gastropod	1.0	0	0.3	0	0.1	0
Miscellaneous						
Oligochaeta	0	28.3	0	14.0	0	47.3
Nematoda	0	7.0	0	6.1	0	4.2

Diets of other fish species

A total of 27 silver salmon smolts were collected from May to November, 15 from streams and 12 from type III lakes. Size ranged from 85 to 200 mm in total length. All fish had been feeding. Midges had a frequency of occurrence of 100% in both lake and stream fish. Lake fish contained the crustacean *C. spinicorne* and aquatic insects while stream fish ate only aquatic insects. Aquatic insects were dominant in frequency of occurrence and volume in fish from both habitats with midge larvae, pupae and adults the most common insects.

Over 2,000 stickleback were collected from May to November. Over 60% came from lakes. Size ranged from 22 to 83 mm in total length. About 80% had been feeding. Aquatic insects were dominant in frequency of occurrence and volume in both habitats with midges the most abundant insect. Crustaceans and nematodes were second in frequency of occurrence and volume on lake fish. Other food items of importance were eggs of stickleback and sculpin, cladocerans, mollusks, and copepods. Ephemeroptera (mayflies) and nematodes were second in importance in stream fish (R. A. Valdez, September 1, 1968, personal communication).

DISCUSSION

Composition of diet

Of 3,672 fish collected from September 1967 to November 1968, 3,100 (86%) had been feeding. Aquatic insects and crustaceans were the most frequently occurring food items and the most abundant by volume. These findings concur with those of Wallis (1948) in Oregon; DeLacy (1941), Roos (1959), and Armstrong (1965b) in Alaska; Savvaitova and Reshetnikov (1961), and Kazaronovski (1962) in Siberia; and Nishio (1934) in Japan who found that invertebrates occurred more frequently and in greater volume than any other food type in the freshwater diet of Dolly Varden.

Aquatic insects were the most frequently occurring item in the diet of Dolly Varden on Amchitka with Diptera the most common insect. The midge in its three life forms was by far the most common dipteran. In the studies mentioned above, aquatic insects were the most common food item with either Trichoptera or Diptera the most abundant insect.

Influence of habitat

There was a marked difference in the composition of diets of Dolly Varden from streams and lakes, and within lake types. This difference could have been due to the fish or to environmental differences. Examination of char from all areas sampled showed them to be the same species whereas examination of all sampling stations revealed marked differences and variations in physical features and benthic fauna.

Aquatic insects were the basic food of fish from streams and type II and III lakes and of secondary importance in fish of type I lakes. These insects were abundant in streams and type II and III lakes but decreased in abundance in type I lakes. Abundance of decaying aquatic vegetation and soft bottom types, basic food and shelter requirements of the dominant aquatic insects on Amchitka, showed similar trends.

Crustaceans, *G. lutea* and *C. spinicorne*, were dominant in the diet of type I lake fish but became proportionately less important in the diet of type III lake, stream, and type II lake fish. They were most abundant in type I lakes and decreased proportionately in type III lakes, streams, and type II lakes. *G. lutea* and *C. spinicorne*, are marine and brackish benthos (Light et al., 1967) that have adapted to freshwater on Amchitka. Firm bottom types, rocks covered with filamentous algae, and adjacency to the sea, possible minimal requirements for these crustaceans (personal observations), are traits which are present in type I lakes, type III lakes, streams, and type II lakes in proportionately decreasing amounts.

There appeared to be a degree of parallelism among the occurrence of food items in stomachs, the abundance of food items in the environment, and the physical features of the habitats. Diet may have been indicating species composition which may have been influenced by bottom type. Diet actually may have been a direct effect of bottom type. Savvaitova and Reshetnikov (1961) observed different diets in lake and stream char in Kamchatka. They attributed this difference primarily to different forms of char present but also to differences in habitat.

Predation on stickleback, sculpin, and their eggs was more than twice as extensive in lake fish as in stream fish. Fish and spawn ranked third in importance in the diet of stream and lake fish as a group but ranked second in the diet of type II lake fish. Sampling indicated that stickleback and sculpin populations were larger in lakes than in streams. This could have accounted for the higher degree of fish predation in lakes. Savvaitova (1961) and Savvaitova and Reshetnikov (1961) observed that isolated char populations tended to be very predaceous. This could explain the high degree of fish predation in type II lakes.

Stream fish ate more pink salmon eggs than did lake fish probably because more pink salmon spawned in streams than in lakes on Amchitka.

Possible reasons for the appearance of marine amphipods in the diet of stream fish were (1) amphipods were washed into streams by wave or tidal action and were eaten by stream fish; (2) stream fish entered the sea, ingested amphipods, then returned to the stream; and (3) fish entered streams with amphipods in their stomachs.

More lake fish in the 100-562 mm range had been feeding than stream fish of similar size. Almost all large non-feeding stream fish were caught during the spring out-migration and could have been out-migrants. Out-migrating fish tend not to feed (DeLacy, 1941; Morton, 1942; Roos, 1959), while non-migrating lake and stream fish usually observe "normal" feeding habits. This could explain the feeding differences between large fish in streams and lakes.

Effects of size

As fish size increased the percentage with empty stomachs became progressively higher. This could indicate that the larger fish ate more sporadically than smaller fish. Smaller fish presumably ate more regularly because of their higher metabolic rate. Roos (1959) found that the proportion of feeding Dolly Varden was highest among the smaller sizes.

As fish size increased, insects became less important in the diet while crustaceans, mollusks, fish, and fish eggs became more important. Insects, generally, were smaller in size than other food items. Therefore, as fish size increased, a change in diet may have reflected the size of the food item that fish were able to ingest rather than the type of food item preferred. Small fish may have been restricted to small food items while larger fish might have been capable of dislodging and capturing large food items.

Seasonal variation

No winter collection of Dolly Varden was made, consequently no statement can be made on winter feeding activity on Amchitka. (The December collection was classified as late autumn since it was made during the first week of the month.) Armstrong (1965a), however, speculates that little feeding occurs in winter, and Logan (1962) found all stomachs empty except one from 107 Dolly Varden collected in January and February at Bare Lake in Alaska.

During summer, feeding activity was at a maximum for lake fish while in spring and autumn it was at a minimum. Summer and autumn had the highest feeding activity for stream fish while the lowest occurred in spring. Roos (1959) also found more Dolly Varden feeding in summer than in spring. Water temperature was higher in summer. This increases the digestive rate and activity of fish (Lagler, Bradach, and Miller, 1962; Brown, 1957), and its prey (assuming the prey is poikilothermic) and could have been one reason for maximum feeding activity during this season. According to the literature out-migrating (usually larger fish) and over-wintering fish tend not to feed; also larger fish tend to migrate to sea where they spend the summer feeding. During summer there was a substantial reduction in the percentage of larger fish in lakes and streams. The higher feeding activity in summer, therefore, could have been due to the absence of this non-feeding component which was present in spring. A large population of potential food items in summer could have been an additional reason for a higher feeding activity during this season.

In May the proportion of stream fish feeding was at its lowest point while it was higher in March and June. In March the proportion of lake fish feeding reached a minimum while it was markedly higher in May. The low proportion of stream fish feeding in May could have been due to the influx of non-feeding, out-migrating lake fish, and non-feeding, out-migrating stream fish. The low proportion of lake fish feeding in March may have been due to the winter fast and the presence of over-wintering migrants. These reasons, along with the possibility of a small food supply, may have accounted for the low proportion of fish feeding during spring.

In September the proportion of stream fish feeding reached a maximum. The diurnal food study (conducted on resident populations in two streams from June to September) showed that feeding reached a maximum in July. This seemed to imply that feeding activity of resident stream fish had been at a maximum in summer but appeared to have occurred in September possibly because of the presence of large numbers of feeding in-migrants. According to Armstrong (1965a) a great amount of feeding occurs while Dolly Varden are at sea and prior to in-migration. Since the September collection had no large numbers of larger fish or high frequencies of occurrence of marine food items, this high feeding activity was probably not due to the presence of in-migrants. One explanation for this high feeding activity could have been the apparent sudden availability of large numbers of midge pupae. These pupae appeared in 63% and were dominant by volume in 52% of the fish. This was one of the highest occurrences observed for a food item throughout the entire study.

Feeding activity in autumn was as high as it was in summer for stream fish. The unusually large occurrence of midge pupae in September and presence of feeding in-migrants could have accounted for this. (The large number of larger fish and high frequency of occurrence of marine amphipods in October and November suggested the presence of in-migrants.)

In autumn, feeding activity for lake fish was as low as it was during spring. This could have been due to a drop in water temperature, a reduction in the food supply, the arrival of in-migrants which stopped feeding after reaching the lakes, and the start of the winter fast by the resident population.

Seasonal changes in diet were primarily due to life history cycles of the food items. This phenomenon has been noted in diets of many fishes (Lagler, Bardach, and Miller, 1962). The individual life form appeared to be abundant in the diet at or about the time it was abundant in the environment. During summer, adult insects predominated with peaks occurring at time of adult emergence (hatches). Pupal forms were most abundant prior to hatches. Larval forms were abundant throughout the year but were most abundant prior to pupation and hatching (in spring and early summer) and after reproduction and development had occurred (in late autumn). Roos (1959) and Armstrong (1965b) observed that insects were most abundant from May to August in Dolly Varden diets in Alaska.

In early spring and late autumn, crustaceans and mollusks appeared more frequently. This was at a time when insects may not have been available or their numbers were low. Fish may have turned to other invertebrates for food when insects were not available.

The occurrence of spawn of stickleback, sculpin, and pink salmon in Dolly Varden stomachs corresponded with spawning times for these fish, late spring to mid-summer, and autumn, respectively. Fish predation in lake fish was high in spring and autumn and low in summer, and visa versa in stream fish. Fish predation in lakes may have been influenced by insect availability and the habits and numbers of the prey. Fish predation in streams may have been influenced by habits and numbers of prey only since insect numbers here appeared to have been seasonally more constant than in lakes.

Influence of maturation

Mature Dolly Varden experienced feeding activities similar to immature fish during summer. A reduction, however, occurred in feeding activity in potential spawners in autumn whether they were in-migrants that had fed at sea or resident fish. Immature residents and in-migrants also experienced a reduction in feeding in autumn. Mature Dolly Varden, however, had a significantly higher percentage of empty stomachs in autumn than did immature fish. This could imply that potential spawners experienced a marked decrease in feeding activity prior to spawning. Feeding becomes sporadic or stops in many mature fish (especially in the Salmonidae family) during spawning season. Morton (1942) and Brunson (1952) found little or no food in stomachs of spawning Dolly Varden.

There was little difference in diets between mature and immature fish of similar size. Some differences occurred however because mature fish were captured in summer and autumn and their diet consisted of food items available at that time while the diet of immature fish reflected a combination of food available in spring, summer, and autumn. The difference in diets between mature and immature stream fish could have been due to the small number of mature fish captured.

Effects of time of day

While no significant difference in stomach fullness due to time of day existed when fish collected from June to September were tested together, there was a significant difference when fish captured in June, July, and August were treated separately. A trend existed which suggested that feeding activity was highest at 0800 hours and decreased steadily to a minimum at 0500 hours. Fish that depend more on sight than on smell for feeding, feed more actively during daylight. A peak in feeding sometimes occurs around sunrise indicating a surge in feeding after a night of forced fasting (Lagler, Bardach, and Miller, 1962). This description could explain the feeding habits of Dolly Varden on Amchitka. Diurnal feeding habits may have been due to activity of prey rather than of fish or a combination of both.

Benthic fauna utilization

When all benthic food items were considered the correlation between occurrence of benthic food items in habitat and in diet was high for streams, moderate for lake type II and essentially nonexistant for lake types I and III. This difference may have occurred because in streams the same food item was abundant in the habitat and diet while in lakes many food items were abundant in the habitat but never appeared in the diet. Also, the Ekman dredge used to sample lake benthos may have been more limited than the screen sampler used in streams. The dredge appeared to collect representative samples of benthic fauna when used in soft bottoms but was unable to accurately sample bottoms covered with stones, rocks, or vegetation. The higher r value in lake type II than in lake types I and III could support this. The accuracy of the screen sampler was influenced to a lesser extent by bottom types because bottom materials were dislodged from all types of substrates and washed onto the screen.

When an item was more abundant in stomachs than in bottom samples (1) the fish may have been selecting this item; (2) the bottom sample may have given a low estimate of its abundance because the area sampled may not have been representative of the benthic environment; or (3) the sampling device may have been incapable of sampling the area. The high numbers of midges in stomachs from lake CO may have indicated selective feeding while the low numbers of *G. lutea* in lakes CB and CF may have represented the inability of the Ekman to sample the rock bottom where this item occurred.

When an item was more abundant in bottom samples than in stomachs (1) the fish may have been ignoring the item; (2) the bottom sample may have given a high estimate of its abundance because the area sampled may not have been representative of the benthic environment; (3) the item may have been in the bottom material, hidden from fish but available to the sampler. The low number of midges in stomachs from lake CB may have implied that they were present but not available, or fish ignored them in favor of crustaceans. The low numbers of ostracods, oligochaetes, nematodes, and flatworms in lake and stream stomachs may have indicated that fish had ignored them because of their small size or that they were buried in the bottom and were not available.

Lake and stream fish apparently ignored smaller food items and fed on larger items approximately in the same proportion as these items occurred in the environment.

Comparison of diets

A comparison of diets of Silver salmon smolts, threespine stickleback and Dolly Varden of similar size feeding in the same habitat revealed some marked differences. The diet of silver salmon smolts consisted of aquatic insects and crustaceans only, while that of stickleback and Dolly Varden was more diverse. Small items such as nematodes, cladocerans, and copepods were more frequent in stomachs of stickleback then in Dolly Varden. Dolly Varden did not rely as heavily on the eggs of stickleback and sculpin as did stickleback. Such differences in diet according to Hynes (1950) suggest that each species is selecting its food and not merely eating what is present. Benthic fauna samples also gave evidence that Dolly Varden on Amchitka were to some degree selective feeders. Dolly Varden appeared to have favored larger food items, such as insects, isopods, amphipods and mollusks while they ignored smaller items, such as oligichaetes, nematodes, cladocerans, and copepods.

SUMMARY AND CONCLUSIONS

Stomach contents of 3,672 Dolly Varden char collected on Amchitka Island, Alaska, from September 1967 to November 1968 were examined to determine the qualitative and quantitative aspects of their food habits. Attention was focused on changes in food habits with habitat (stream *vs* lake), fish size, time (seasonal and diurnal), and sexual development. A comparison was made between benthic fauna abundance and benthic fauna utilization by char with the use of bottom samples. Food habits of threespine stickleback and silver salmon smolts feeding in the same area as the char were examined to determine if Dolly Varden were selective feeders.

Two aquatic invertebrate groups, insects and crustaceans, were the primary components of the diet. Midges, isopods,and amphipods were the most important items in these groups.

During September 1967 1,216 Dolly Varden were captured. Of the 1,024 stream fish 88% had been feeding and aquatic insects were the dominant food items. Of the 192 lake fish 85% had been feeding. Here crustaceans and aquatic insects were the dominant food items. Of the 192 lake fish 85% had been feeding. Here crustaceans and aquatic insects were the dominant food items.

The remaining 2.456 fish were collected from December 1967 to November 1968. Over 83% of these fish had been feeding. In the 889 stream fish 80% had been feeding. Aquatic insects were the most important component of the diet of these fish. Of 1,567 lake fish 85% had been feeding. Aquatic insects and crustaceans were the most important components of the diet of these fish.

Lakes were placed into one of three class types by nature of their bottom type and access to the sea. Type II lakes were landlocked throughout most of the year. Type I and III lake bottoms were silt covered away from shore and had seasonally uninterrupted drainage to the sea. Type I lakes had firm, rock covered bottoms adjacent to shore while type III lakes had muck bottoms adjacent to shore. Type III lakes had more rooted aquatic vegetation than type I lakes.

In the 672 fish from type I lakes 88% had been feeding. Crustaceans, followed by aquatic insects were the most important food items in their diet. Of 78 fish from type II lakes 87% had been feeding. Aquatic insects and fish and fish eggs were the primary food items in the diet of these fish. The 817 fish from type III lakes had 81% feeding. Aquatic insects, followed by crustaceans, were the most important food items in their diet.

Lake and stream fish obtained over 90% of their diet from the aquatic environment. Invertebrates accounted for more than 85% of the diet. Aquatic insects and crustaceans were 49% and 33%, respectively, by volume of the diet of lake fish while aquatic insects were almost 74% by volume of the diet of stream fish. Fish, fish eggs, and mollusks were more than twice as abundant in the diet of lake fish as in stream fish.

Fish of the smallest size class had the highest proportion of feeders. This proportion became progressively smaller in each larger size class. Smaller fish had a high frequency of occurrence and dominance by volume of aquatic insects. Larger fish had a high frequency of occurrence and dominance by volume of crustaceans, fish, fish eggs, and mollusks.

The highest feeding activity for stream fish occurred in summer and autumn while the lowest occurred in spring. May had the lowest percentage of feeding fish (59%) while September had the highest (94%). During summer, feeding activity was at a maximum for lake fish while it was at a minimum in spring and autumn. July had the highest percentage of feeding fish (93%) while March had the lowest (63%).

During summer, aquatic insects were dominant in the diet of lake fish while crustaceans and fish were dominant in spring and autumn. During all seasons sampled, aquatic insects were dominant in the diet of stream fish. During spring and autumn, fish and crustaceans appeared more often in the diet of stream fish than during summer.

Adult and pupal aquatic insects appeared in the diet primarily during summer while larval forms were present during all seasons sampled. The occurrence of spawn of stickleback, sculpin, and pink salmon in Dolly Varden stomachs corresponded with spawning times for these fish.

A total of 426 mature fish were captured from July to December, 403 from lakes and 23 from streams. Mature fish appeared to eat more sporadically than immature fish in early autumn, prior to spawning, and had a significantly higher percentage of empty stomachs than did immature fish. There was little difference between diets of mature and immature fish of similar size captured in the same season.

Analysis of 384 fish collected from two streams from June to September showed no significant difference in stomach fullness due to time of day. When fish from each month were tested separately, a significant difference in stomach fullness due to time of day did exist for each month except September, with a mean stomach fullness low at the 0500 hour and a high at the 0800 hour. Thus feeding activity appeared to have been lowest prior to dawn and highest after dawn. Also, more feeding had occurred during daylight hours than at night. There was little difference in type of food eaten due to time of day; aquatic insects were the major food items ingested at all hours.

Bottom samples were collected from two streams and three lakes (one of each type) from June to October. The benthos collected in these samples were compared to stomach samples from fish taken at each station during the same period. The degree of correlation between occurrence of benthic food items in habitat and in diet was high for streams, moderate for lake type II, and essentially non-existent for lake types I and III when all benthic food items were considered. Lake and stream fish generally ignored smaller food items and fed on larger items approximately in the same proportion as these items were present in the environment.

A total of 27 silver salmon smolts were collected. All had been feeding and all contained midges. Lake fish also contained crustaceans while stream fish contained only aquatic insects. Aquatic insects were dominant in frequency of occurrence and volume in all fish.

Over 2,000 stickleback were collected with 60% coming from lakes. Over 80% of all fish had been feeding. Aquatic insects were dominant in frequency of occurrence and volume. Crustaceans and nematodes were second in frequency of occurrence and volume in lake fish. Spawn and small items, such as oligochaetes, cladocerans, and copepods were also consumed.

Analysis of food habits of co-inhabitating fish species and Dolly Varden of similar size and the results of benthic fauna sampling indicated that while Dolly Varden ate what was present they exhibited some degree of selective feeding. They generally ignored small items, such as nematodes, copepods, oligochaetes, and cladocerans, which were ingested by stickleback, in favor of larger food items such as aquatic insects, isopods, and mollusks.

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